Thermal Properties of Materials

Question paper 4

Level	International A Level
Subject	Physics
Exam Board	CIE
Topic	Thermal Properties of Materials
Sub Topic	
Paper Type	Theory
Booklet	Question paper 4

Time Allowed: **64 minutes**

Score: **/53**

Percentage: **/100**

A*	A	B	C	D	E	U
>85%	'77.5%	70%	62.5%	57.5%	45%	<45%

1 **(a)** The equation

$$pV = constant \times T$$

relates the pressure p and volume V of a gas to its kelvin (thermodynamic) temperature T.

State two conditions for the equation to be valid.

1. ....

....

2. ....

.... [2]

(b) A gas cylinder contains $4.00 \times 10^4\,cm^3$ of hydrogen at a pressure of 2.50×10^7 Pa and a temperature of 290 K.

The cylinder is to be used to fill balloons. Each balloon, when filled, contains $7.24 \times 10^3\,cm^3$ of hydrogen at a pressure of 1.85×10^5 Pa and a temperature of 290 K.

Calculate, assuming that the hydrogen obeys the equation in **(a)**,

(i) the total amount of hydrogen in the cylinder,

amount = ……………………….. mol [3]

(ii) the number of balloons that can be filled from the cylinder.

number = ……………………….. [3]

2 **(a)** State the first law of thermodynamics in terms of the increase in internal energy ΔU, the heating q of the system and the work w done on the system.

....

.... [1]

(b) The volume occupied by 1.00 mol of liquid water at 100 °C is $1.87 \times 10^{-5}\,\text{m}^3$. When the water is vaporised at an atmospheric pressure of 1.03×10^5 Pa, the water vapour has a volume of $2.96 \times 10^{-2}\,\text{m}^3$.
The latent heat required to vaporise 1.00 mol of water at 100 °C and 1.03×10^5 Pa is 4.05×10^4 J.
Determine, for this change of state,

(i) the work w done on the system,

w = ... J [2]

(ii) the heating q of the system,

q = ... J [1]

(iii) the increase in internal energy ΔU of the system.

ΔU = ... J [1]

(c) Using your answer to **(b)(iii)**, estimate the binding energy per molecule in liquid water.

energy = ……………………………… J [2]

3 **(a)** Define *specific latent heat of fusion*.

....

....

....[2]

(b) A mass of 24 g of ice at –15 °C is taken from a freezer and placed in a beaker containing 200 g of water at 28 °C. Data for ice and for water are given in Fig. 3.1.

	specific heat capacity / $J\,kg^{-1}\,K^{-1}$	specific latent heat of fusion / $J\,kg^{-1}$
ice	2.1×10^3	3.3×10^5
water	4.2×10^3	–

Fig. 3.1

(i) Calculate the quantity of thermal energy required to convert the ice at –15 °C to water at 0 °C.

energy = ... J [3]

(ii) Assuming that the beaker has negligible mass, calculate the final temperature of the water in the beaker.

temperature = ... °C [3]

4 The first law of thermodynamics may be expressed in the form

$$\Delta U = q + w,$$

where U is the internal energy of the system,
ΔU is the increase in internal energy,
q is the thermal energy supplied to the system,
w is the work done on the system.

Complete Fig. 6.1 for each of the processes shown. Write down the symbol '+' for an increase, the symbol '–' to indicate a decrease and the symbol '0' for no change, as appropriate.

	U	q	w
the compression of an ideal gas at constant temperature			
the heating of a solid with no expansion			
the melting of ice at 0 °C to give water at 0 °C (Note: ice is less dense than water)			

[6]

Fig. 6.1

5 The volume of some air, assumed to be an ideal gas, in the cylinder of a car engine is 540 cm^3 at a pressure of 1.1×10^5 Pa and a temperature of 27 °C. The air is suddenly compressed, so that no thermal energy enters or leaves the gas, to a volume of 30 cm^3. The pressure rises to 6.5×10^6 Pa.

(a) Determine the temperature of the gas after the compression.

temperature = ... K [3]

(b) **(i)** State and explain the first law of thermodynamics.

....

....

....

.... [2]

(ii) Use the law to explain why the temperature of the air changed during the compression.

....

....

....

....

....[4]

6 (a) On Fig. 2.1, place a tick (✓) against those changes where the internal energy of the body is increasing. [2]

water freezing at constant temperature	....
a stone falling under gravity in a vacuum	....
water evaporating at constant temperature	....
stretching a wire at constant temperature	....

Fig. 2.1

(b) A jeweller wishes to harden a sample of pure gold by mixing it with some silver so that the mixture contains 5.0% silver by weight. The jeweller melts some pure gold and then adds the correct weight of silver. The initial temperature of the silver is 27 °C. Use the data of Fig. 2.2 to calculate the initial temperature of the pure gold so that the final mixture is at the melting point of pure gold.

	gold	silver
melting point / K	1340	1240
specific heat capacity (solid or liquid) / $J\,kg^{-1}\,K^{-1}$	129	235
specific latent heat of fusion / $kJ\,kg^{-1}$	628	105

Fig. 2.2

temperature = ... K [5]

(c) Suggest a suitable thermometer for the measurement of the initial temperature of the gold in **(b)**.

.... [1]

7 A kettle is rated as 2.3 kW. A mass of 750 g of water at 20 °C is poured into the kettle. When the kettle is switched on, it takes 2.0 minutes for the water to start boiling. In a further 7.0 minutes, one half of the mass of water is boiled away.

(a) Estimate, for this water,

(i) the specific heat capacity,

specific heat capacity = ... $J\,kg^{-1}\,K^{-1}$

(ii) the specific latent heat of vaporisation.

specific latent heat = ... $J\,kg^{-1}$
[5]

(b) State **one** assumption made in your calculations, and explain whether this will lead to an overestimation or an underestimation of the value for the specific latent heat.

....

....

....[2]